U.S. Atomic Energy Commission's Environmental Research Programs Established in the 1950s

History of the Atomic Projects, The 50s Years:
Sociopolitical, Environmental, and Engineering Lessons Learned

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In 1946 the United States (U.S.) Congress passed the Atomic Energy Act and with it created the Atomic Energy Commission. For the ensuing half-century the AEC and its successors have pursued biological and environmental research with an unwavering mandate to exploit the use of fissionable and radioactive material for medical purposes and, at the same time, to ensure the health of it's workers, the public, and the environment during energy technology development and use (AEC. 1961; DOE 1983; DOE, 1997). The following pages are testimony to the success of this undeviating vision (Figure 1). From the early days of the AEC, cooperation has also linked researchers from the national laboratories, the academic community, and the private sector. The AEC-sponsored research both at national laboratories and universities, and also supported graduate students to develop a cadre of health physicists, radiation biologists, and nuclear engineers. Coordinating these diverse performers has been crucial to the unique teaming that has made many of the successes possible. The success of the biological and environmental research program has often been shared with other federal agencies. The future will demand even stronger and more substantive intraagency, interagency, and international collaborations.

The earliest glimmering of radioactivity’s promise long predated any sense that ours would be the Atomic Age. By the time of the Manhattan Project, physicists had almost a half-century of experience with x-rays and radioactive elements and their radiation, and several such elements, most notably radium, had been used since the turn of the century in efforts to treat human disease. By the 1930s, radioactive isotopes were being produced artificially in Berkeley’s cyclotrons, and the pace of medical use and biological experimentation increased dramatically. At the same time, even the earliest pioneers saw that radioactivity was not a benign blessing; protection standards, albeit far from adequate, were published as early as 1915. Nonetheless, it was World War II that firmly thrust the nuclear genie onto the public stage. At first, the spotlight was on the awesome power of the atom, then on the emerging promise of nuclear energy, but splitting the atom would also herald a vital new era for biology, medicine, and environmental research (Stannard, 1988).

Even during the war years, biological research was a priority. A Medical Advisory Committee chaired by Stafford Warren developed health and safety policy for the Manhattan Project and inaugurated research programs to assure adequate protection for Project workers. Teams of physicians, biologists, chemists, and physicists worked to learn how isotopes and their radiation affected the body, what protective measures were most effective, and in the event of mishap, what methods of diagnosis and treatment were best. At the war's conclusion, recognizing the opportunities of atomic energy—and acknowledging, too, an obligation for public safety—the Congress passed the Atomic Energy Act of 1946, which would transfer responsibility for atomic energy research and development from the War Department to an independent civilian agency, the Atomic Energy Commission. On January 1, 1947, the AEC thus took charge of research programs in health measures and radiation biology conducted in government facilities at the Clinton Laboratories (now Oak Ridge National Laboratory), Hanford, and Los Alamos; at the Metallurgical Laboratory at the University of Chicago (now Argonne National Laboratory); and at many university laboratories, large and small. Among the ongoing efforts were health physics research for "improving our knowledge of the potential dangers presented by fissionable materials, reactors, and fission products and for proposing methods of elucidating or circumscribing such dangers"; research aimed at extending our "fundamental knowledge of the interaction of nuclear radiation and living matter"; and radioisotope distribution programs to "provide indirect aid to research in many fields of biological and medical research." The entire Commission budget for fiscal 1947 was $342 million; only a fraction of which was for biological, medical, and environmental research.

Early in its first year, the AEC moved to provide a solid foundation for its biomedical research and education efforts by asking the President of the National Academy of Sciences to nominate a panel of experts as a Medical Board of Review to advise the Commission. The Board was promptly established, and by June it had issued its initial recommendations, broadly supporting biomedical research and training efforts and proposing a permanent Advisory

Committee for Biology and Medicine (ACBM). In September 1947, the chairman of the AEC appointed seven distinguished physicians and biologists to the ACBM.

Immediately upon its creation, the ACBM recommended that a Division of Biology and Medicine be established to “coordinate medical, biological, and biophysical (health physics) research programs related to atomic energy” and to “direct for the Commission its health physics works and industrial hygiene activities.” The recommendation was quickly adopted. Thus was forged a commitment that has endured for a half-century—a commitment to vigorous research aimed both at nurturing the fruitful use of a new technology in the life sciences and at ensuring public health and safety in the face of that technology's perils. In 1955 Dr. Charles Dunham became director of the AEC Division of Biology and Medicine and in 1956 created the Environmental Research Branch (with John Wolfe as director) for "research pertaining to man and his environment, including disciplines such as ecology, oceanography, marine biology, geophysics, and meteorology." The historical timeline for these organizations in the AEC, and its successors, is shown In Figure 2.

In matters of the environment, public awareness lagged far behind the activities of the energy agencies. As early as the forties and fifties, in an era when most people had never even heard the word “ecology,” the AEC was forging an enviable record of environmental and ecological research. The initial catalyst was again the development of nuclear weapons and the two decades of atmospheric testing that followed. Estimating the health effects of released radioactivity depended not only on epidemiology, genetics, and radiation biology, but also on knowing the fates of the airborne radioisotopes in the first place. Meteorology and oceanography were no less important than biology—as was research into the ecological processes that cycled materials through plants and animals to human beings. Atmospheric and environmental studies thus fell naturally within the purview of biomedical research. The impact of atomic energy on the environment and on the environmental sciences was profound (Wolfe, 1963).

The Atmosphere

In the postwar years, responsibility for radioactive fallout monitoring was spread among several laboratories. Chief among them was the Health and Safety Laboratory (now the Environmental Measurements Laboratory) in New York City, which established the earliest and most authoritative monitoring network in the world—and ultimately produced an integrated history of the distribution of nuclear weapons debris in the air, on land, and in water, as well as in plants and animals, especially the human food chain. As part of the High-Altitude Sampling Program, for example, instrumented balloons and aircraft were sent aloft to sample the stratosphere and to assess the exchanges of material between the stratosphere and the lower atmosphere. The resulting data contributed in a concrete way to the international moratorium on above-ground testing later in 1963.

Beyond measurement, however, lay the more daunting challenge of prediction—a challenge that would naturally breed three distinct research thrusts: inquiries into the transport of radioactive materials released near the ground (a situation that might arise following, say, an accident at a weapons production facility), research into how clouds scavenge radionuclides and then deposit them in rain, and efforts to understand the global transport of materials released during atmospheric weapons tests.

In pursuit of answers to the near-surface question, several of the national laboratories installed meteorological facilities, including several Air Resources Laboratory (ARL) facilities operated by the U.S. Weather Bureau for the AEC. Their investigators sought scientific methods to predict how airborne materials are transported in the lower atmosphere and how their eventual deposition depends on the nature of the material and on atmospheric and topographic variables, including the presence of complex mountainous terrain. Using the collective results of these efforts, Frank Gifford and his colleagues at the ARL Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge then developed a set of curves for calculating the spread of pollution from a "point source." In a time when the slide rule was the dominant computational tool, these dispersion models won international acceptance as tools for predicting the fate of nuclear reactor emissions and industrial pollutants.

A natural part of the effort to understand atmospheric dynamics was the use of tracers to track the movement of materials, both locally and around the globe—not unlike the use of radionuclides to follow dynamic processes in the human body. Early "tracers of opportunity" included such natural constituents of the atmosphere as spores and ozone, as well as power plant emissions and debris from weapons tests. In at least one case, a nuclear weapon was even "salted" with tungsten, which could be conveniently traced around the world. In 1955, early efforts to understand atmospheric transport and dispersion led to the publication of *Meteorology and Atomic Energy*, which quickly became a basic meteorological reference. A second edition, published in 1968, would for years remain the definitive reference for small-scale meteorology. By 1984 it had evolved into the 850-page volume, *Atmospheric Science and Power Production* (Randerson, 1984).

Climate

In the area of atmospheric studies, the legacy of the fifties and sixties has thus been especially fertile. But perhaps the richest payoff has been a heightened awareness of our atmosphere’s complexity and, in turn, a keener appreciation of its sensitivity to human activity. The third of the AEC’s major research thrusts—atmospheric dynamics on a global scale—contributed in an especially important way to this growing environmental awareness. In the early sixties, the AEC’s interest was the global transport of weapons test debris. Accordingly, at Livermore, mathematical physicist Cecil Leith was one of only a handful of researchers in the world using the emerging power of scientific computing to simulate global atmospheric dynamics. Later, he would move on to the new National Center for Atmospheric Research (NCAR) in Boulder, Colorado, where he established its reputation as one of the world’s leaders in developing atmospheric general circulation models (GCMs)—advanced climate models that provide not short-term meteorological forecasts, but rather long-range prognoses of global climate.

Today, global climate change research continues as a vigorous multiagency priority, propelled by the issue’s overarching importance and challenged by the profound complexity of atmospheric and biological processes. The DOE is now one of several federal agencies, notably NASA, the National Science Foundation, and the National Oceanic and Atmospheric

Administration, working as partners to predict future concentrations of greenhouse gases, to assess their likely effects on the climate, and to evaluate the resulting biological and economic impacts.

The Dynamic Ocean

Perhaps even more deeply mysterious than atmospheric dynamics are the workings of the oceans. From the earliest days of atmospheric testing, the AEC sought to understand the fate of radioactive fallout over Pacific waters and whether radioactive waste could be safely disposed of in the ocean depths. But the agency's interest was greatly heightened in 1954, when a Japanese fishing boat and its cargo of fish were contaminated following a Pacific Ocean nuclear test. Suddenly, the sea and its denizens were subjects of intense inquiry. Ensuing AEC support for oceanic research reaped unexpected rewards.

One of the pioneers was Wallace Broecker, of Columbia University's Lamont-Doherty Geological Observatory (now the Lamont-Doherty Earth Observatory). Soon after the 1954 incident, he began using natural and bomb-generated radionuclides as "clocks" to study ocean dynamics. By measuring the ratios of carbon isotopes, for example, he found that, whereas the average CO_2 molecule remains in the atmosphere for seven years, bottom water in the Pacific Ocean turns over only once every thousand years. His analyses of CO_2 absorption by the oceans also provided new data on the fate of atmospheric CO_2 more than a decade before it would become an important climate change issue. Broecker's methods were seminal: Distributions of stable and radioactive isotopes were subsequently used to measure the accumulation rates of deep-sea sediments and to develop the first records of climate change in the past. Broecker also turned to radionuclides as tracers. Using strontium-90 from fallout, for example, he was able to define the Atlantic Ocean "conveyor belt" that operates between Greenland and the equatorial tropics. In 1996, in part for work supported by the AEC, he was awarded the Presidential Medal of Science.

The Biosphere

This prescient work on ocean ecosystems points, in fact, to yet another strand of environmental research, one intricately entwined with studies of atmospheric and oceanic dynamics and the dispersion of air- and waterborne contaminants. Its early theme was the fate and effects of radioactivity released into terrestrial and fresh-water ecosystems. In concert with research on human health effects, these strands of environmental exploration thus sought a complete picture of the impacts of nuclear technology: What is the fate of the radioactive materials we release? What are their direct effects on humans? And what are their near- and long-term effects on the biosphere of which we are a part? The early efforts would broaden decades later in the seventies to encompass all energy-related emissions, but the larger question would remain the same: What are the consequences of the energy choices we make?

In approaching such questions, the AEC's most pervasive contribution followed the theme of its efforts in nuclear medicine and atmospheric studies, namely, the use of radioactive tracers. Beginning with modest efforts at several universities and national laboratories (Caldecott and Snyder, 1959), radioecology grew to encompass studies of material pathways and flow rates through terrestrial and aquatic ecosystems of every description (Klement and Schultz, 1963). The research involved nearly all of the AEC national laboratories, in part because of their locations in different environments of the country (Figure 3).

At first, radiotracer studies led by Richard Foster dealt mainly with iodine-131, a short-lived fission product deposited on the landscape from weapons-material production plants, and with radioactive products released into the Columbia River from the reactors at Hanford (Stannard, 1988). Later, nuclear testing led to the spread of radioactive cesium and strontium isotopes, which prompted research projects on soil migration, root uptake, uptake by grazing and browsing animals, and transfer to food products. A major part of the aquatic research was conducted at Oak Ridge, Hanford, and Savannah River, whereas much of the work on soils, plant uptake, and the dairy pathway was done at agricultural schools within major universities. Together, these research efforts pioneered the quantitative study of environmental processes and provided not only the mechanistic understanding, but also the historical databases that supported the DOE's early environmental restoration program, and that underlie today's ongoing cleanup of contaminated defense sites.

But the first ecological research linked to the nuclear era focused on radioactivity's direct effects—work that predated even the AEC (DOE, 1997). Studies by Al Seymour, fisheries scientist from the University of Washington, were aimed at assessing the possible effects of effluents from Hanford's wartime reactors. And by 1946 the region's sheep and cattle were being monitored for radioactive iodine uptake. Nor was the plant kingdom ignored. For thirty years, starting in 1949, Brookhaven scientists led by Arnold Sparrow studied the effects of radioactivity on plants, first on introduced species and plants of economic importance and later on native species. An important result of this work was the discovery that the volume of the cell nucleus in different plant species was an important factor in determining the species' relative sensitivity to radiation.

In 1950, using phosphorus-32 in a Connecticut lake, Evelyn Hutchinson at Yale documented the quantitative cycling of the element—an essential and often limiting nutrient—within a lake ecosystem. Then, in 1951, the AEC took a major step toward the systematic study of ecology: The agency granted $10,000 each to the University of South Carolina and the University of Georgia to conduct a biological inventory of the Savannah River site, in preparation for constructing a facility there to produce materials for nuclear weapons. Eugene Odum led the Georgia effort, in time putting together a research center of international repute, first called the Laboratory of Radiation Ecology, then the Savannah River Ecology Laboratory. Early studies of plant succession and pioneering applications of radiotracers to the study of food chains and food webs led to studies of wetlands ecology, endangered species of the Southeast, regional biodiversity, and the environmental chemistry of trace metals.

Also in the fifties, the AEC created its Environmental Sciences Branch led by the visionary John Wolfe to support studies of terrestrial, freshwater, and marine systems, with the emphasis on the long-term fate and effects of radionuclides. In this encouraging environment, Stanley Auerbach at Oak Ridge National Laboratory shifted his emphasis from laboratory experiments to field work focused on how radionuclides might migrate through the food chain, from water and soil to plants, animals, and humans. A particular public worry, for example, was strontium-90, which can reach humans via cattle fodder and cow's milk and then accumulate at dangerous levels in bones. As a result of his pioneering fieldwork, Stanley Auerbach would establish the country's leading ecological research program (Auerbach, 1993).

Auerbach and his colleagues pursued some of their first studies in the dry bed of White Oak Lake, where Oak Ridge once flushed low-level radioactive wastes. In the course of their studies, Oak Ridge ecologists introduced computer simulations to ecological science, a striking innovation in 1958. Products of this and other AEC research on radionuclide transport and bioaccumulation still provide the basis for models used to assess the impact of radioactive emissions on living organisms, including humans.

In the early sixties, attention at Oak Ridge shifted to the "cesium forest," a stand of radiolabeled tulip poplars, which produced some of the first research to document the extent to which an element is recycled within a forested ecosystem. Stimulated by earlier assessments of the environmental fate of ^{14}C releases from light water reactors, these efforts then later expanded in 1966 to include ecosystem metabolism. These studies developed the scientific foundation for the DOE’s later interests in greenhouse gases and terrestrial carbon cycling research and became the centerpiece for the International Biological Program’s global woodlands research effort beginning in 1968 (Reichle, 1981). Concurrently, ecologists launched the Walker Branch Watershed project, which continues today, one of the two longest-running studies of a forest ecosystem in the U.S. Over the years, it has afforded deep insights into the flow of nutrients, water, and contaminants through a forested watershed and on the physical, chemical, and biological processes that control this flow. More broadly, it has provided new tools for evaluating the effects of human activities on natural environments.

The AEC was no less committed to supporting ecological research in universities, where ecologists and limnologists used tracers to study the transport of materials in lakes and rivers, sometimes using entire small lakes as experimental ecosystems. In 1951, for example, Arthur Hasler at the University of Wisconsin took a whole-ecosystem approach in testing a way to manipulate algal and fish production. He separated the two halves of an hourglass-shaped lake in northern Wisconsin with an earthen barrier, thus creating two separate lakes. One was then treated with lime to reduce the acidity and thus the concentration of dark organic matter in the water, while the other remained untreated as a control. In 1960 University of Wisconsin scientists used radiosodium and radioiodine to document the physical and biological mechanisms of material mixing and transport in a chemically stratified lake. Thus, early efforts such as this paved the way for much of modern limnology by offering key insights into how lake ecosystems work and how they might be managed to enhance their intrinsic and utilitarian values.

By the late fifties, thoughtful scientists had become deeply aware of the intricacy and sensitivity of the ecological web. At the same time, proponents of the Plowshare program were proposing to use nuclear detonations to excavate harbors and construct canals. To pave the way for such projects, an experimental harbor excavation, dubbed Project Chariot, was proposed for (Wilmovsky and Wolfe, 1966) in northwest Alaska. In a landmark effort, the AEC sent a team of scientists to survey the area beforehand—the first major ecological survey ever done in advance of proposed development. Among the goals were to gather enough information to allow credible estimates of the biological cost of the harbor project and to establish a baseline for assessing future change, natural and otherwise. In the end, the study contributed more basic ecological information about the Arctic than all previous investigations combined. Further, it suggested that Project Chariot would entail unacceptable ecological and public health risks, and, perhaps most important, it presaged a new era of ecological awareness, almost a decade before the National Environmental Policy Act of 1969 would demand such environmental impact assessments.

The Legacy of the 1950s

The DOE's Office of Biological and Environmental Research (OBER) currently supports research at more than 800 research projects at institutions around the country—a research portfolio that, for all its diversity, reflects a direct lineage from the earliest charge to the AEC -- to exploit the promise of a new age and to safeguard the public health in the face of its uncertainties (DOE, 1997; Stannard, 1988). And yet, this constancy of purpose has demanded inevitable change, as new ideas have emerged, as tools have evolved, and as the foundation of knowledge has grown. Underscoring this truth is the example of the AEC's interests in biogeochemical cycling and ecosystem metabolism, and the establishment by DOE in 1972 of National Environmental Research Parks (Figure 3) as its continuing commitment to ecological research (DOE, 1977). Seen in this light, the birth of the global change research program within the Biological and Environmental Research (BER) program is no surprise.

The pioneers of biological and environmental research within the AEC could hardly have predicted the course BER research would take (DOE, 1997). Efforts focused on the fate of radioactive fallout would evolve into today's global climate research. Exploratory studies of ecosystem metabolism using radiotracers would lead to the first estimates of net ecosystem production and global carbon exchanges by the biosphere. And questions raised by early epidemiological studies would ultimately give rise to quantifying food chain dynamics and exposure pathways, providing the basis for regulatory standards for radionuclides and hazardous chemicals. The next fifty years are equally unpredictable. The future, as usual, promises unknown challenges—and unexpected opportunities. It is certain only that as technology evolves, so will our responsibilities for understanding the impact of our decisions on human health and the health of our environment. And as long as our well-being depends on the wisdom of our choices, the enduring mandate of the AEC will continue to inform the research of the DOE scientists charged with its legacy.

Figure 1. Milestones in the U.S. Atomic Energy Commission's (now Department of Energy) environmental research program during the decade of the 1950s.

1946 The Atomic Energy Act of 1946 establishes the Atomic Energy Commission (AEC). Radioecological studies of the Hanford environs and the Columbia River lab by Richard Foster and Jerry Davis are already under way.

1947 The AEC establishes the Division of Biology and Medicine (will later be known as Division of Biomedical and Environmental Research [1974], Office of Health and Environmental Research [1977], Office of Biological and Environmental Research [1997])

1949 Brookhaven scientists begin a thirty-year program aimed at assessing the effect of radiation on living plants. Much of the work would take place at the cultivated Gamma Field established in 1951. Results here and at Oak Ridge would confirm Brookhaven predictions that relative radiosensitivity among plant species varies with nuclear volume and chromosome size.

1950 Using phosphorus-32 in a Connecticut lake, Evelyn Hutchinson at Yale documented the quantitative cycling of the element—an essential and often limiting nutrient—within a lake ecosystem. Initial radioecological survey at Oak Ridge conducted by Louie Krumholz of the Tennessee Valley Authority.

1951 The AEC supported the establishment of the Laboratory of Radiation Ecology at Savannah River, directed by Eugene Odum of the University of Georgia.

1955 At the First International Conference of the peaceful Uses of Atomic Energy in Geneva, Switzerland, Richard Foster and Jerry Davis summarize nearly a decade of measurements in the behavior of radionuclides in Columbia River waters and aquatic biota at the Hanford Site.

1955 The radioecology program in Oak Ridge is formally established by Stanley Auerbach who initiates over the next two years the first experimental radioecological studies in terrestrial ecosystems on White Oak Lakebed. Ed Struxness and Frank Parker initiate the Clinch River health physics studies of off-site movement of radionuclides.

1955 Early efforts to understand atmospheric transport and dispersion led to the publication of *Meteorology and Atomic Energy,* which quickly became a basic meteorological reference. A second edition, published in 1968, would for years remain the definitive reference for small-scale meteorology. By 1984 it had evolved into the thousand-page volume, *Atmospheric Science and Power Production.*

1956 The Environmental Research Branch was created within the AEC's Division of Biology and Medicine for "research pertaining to man and his environment, including disciplines such as ecology, oceanography, marine biology, geophysics, and meteorology."

1959 Symposium on Radioisotopes in the Bisophere at the University of Minnesota overviews the environmental concerns and knowledge at the end of the decade.

1959 Wallace Broecker at Columbia University used natural radiocarbon in the ocean to quantify ocean circulation processes.

1960 In advance of the proposed use of nuclear explosions to excavate a harbor near Cape Thompson, Alaska, AEC-sponsored scientists began an exhaustive ecological survey of the area. This "environmental assessment" predated by almost a decade the requirements of the National Environmental Policy Act of 1969.

1960 University of Wisconsin scientists used radiosodium and radioiodine to document the physical and biological mechanisms of material mixing and transport in a chemically stratified lake.

1961 The research of the 1950s summarized at the First International Symposium on Radioecology (organized by Vince Schultz and Art Klement, Jr., in Fort Collins, Colorado.

Figure 2. Timeline and Organizational Nomenclature

1946 Atomic Energy Commission (AEC) established

- 1947 Division of Biology and Medicine (DBM) established

- 1956 Environmental Research Branch created in DBM

1974 AEC renamed Energy Research and Development Administration (ERDA)

- 1974 Division of Biology and Medicine renamed Division of Biomedical and Environmental Research

1977 ERDA renamed Department of Energy (DOE)

- 1977 Division of Biomedical and Environmental Research renamed Office of Health and Environmental Research (OHER)

- 1997 Office of Health and Environmental Research renamed Office of Biological and Environmental Research (OBER)

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